CISCOR

CENTER FOR INTELLIGENT SYSTEMS, CONTROL, AND ROBOTICS

Team 10
GOLIATH Autonomous ATV

Group Members:

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Instructor:

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Background/Needs

- CISCOR focuses on mobile robotic path-planning
- Requires a more robust autonomous off-road platform
- Previous work included remote control
- Actuators installed

Objectives

- To integrate a sensory system that will scan the surrounding environment
- Use data to compute a trajectory to perform waypoint navigation and road following autonomously
- Will be used as a future research platform for CISCOR

Constraints

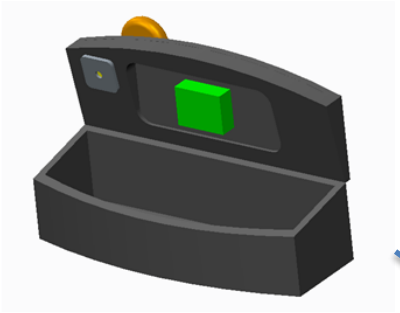
- Sensors/ATV
  - Team must work with previously purchased sensors and ATV
- Budget
  - 1500.00 USD
- Time
  - 32 weeks for project completion

Sensor Overview

IMU

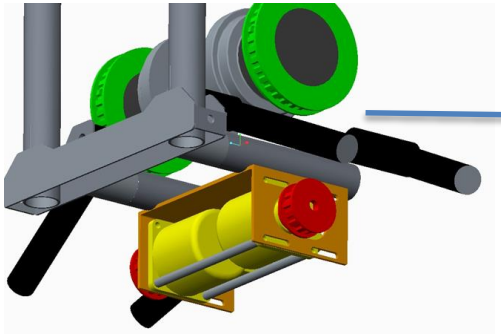
Steering Motor

GPS

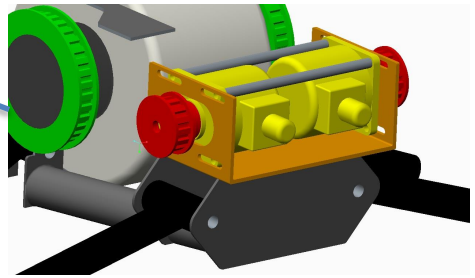


SICK Laser

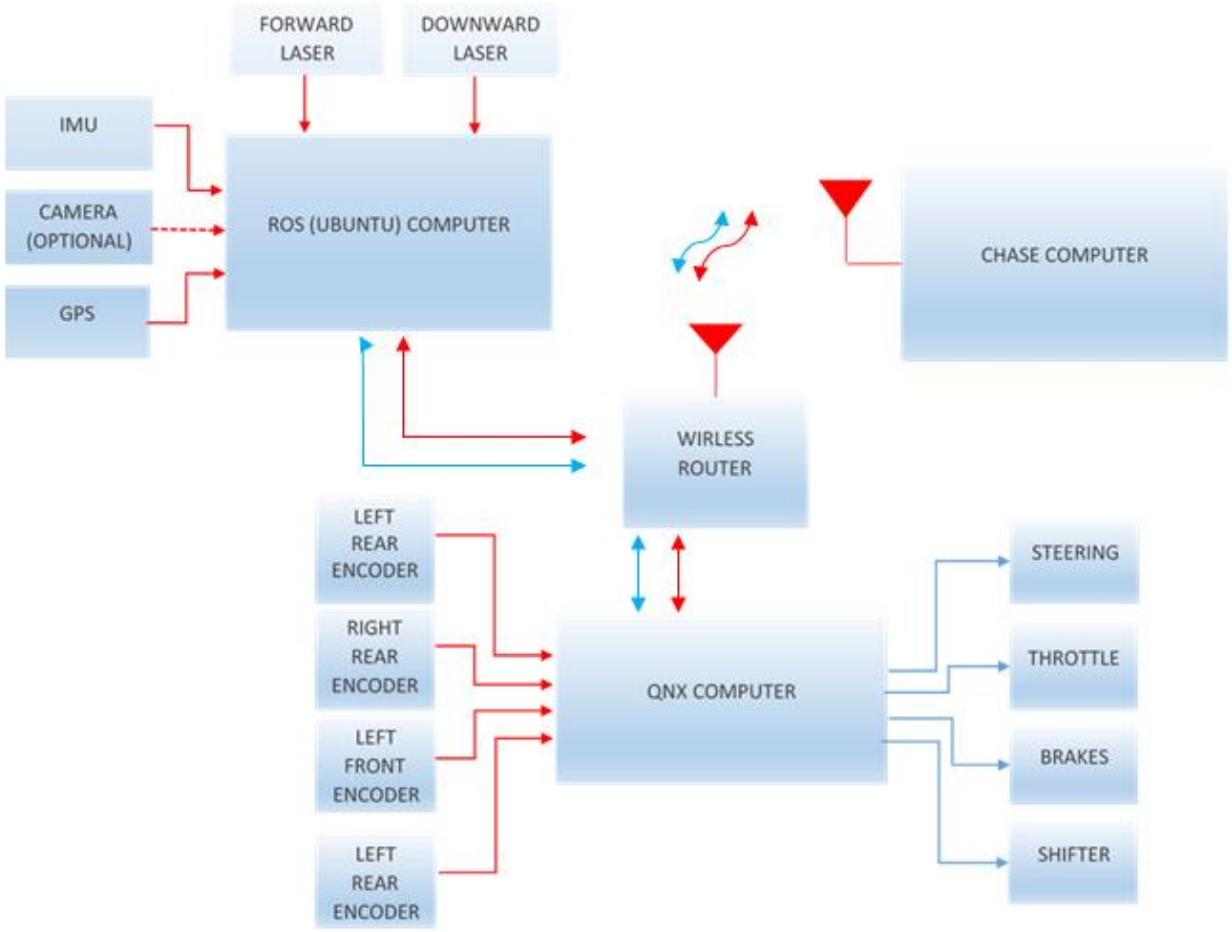
Rear Encoder



Front Encoder



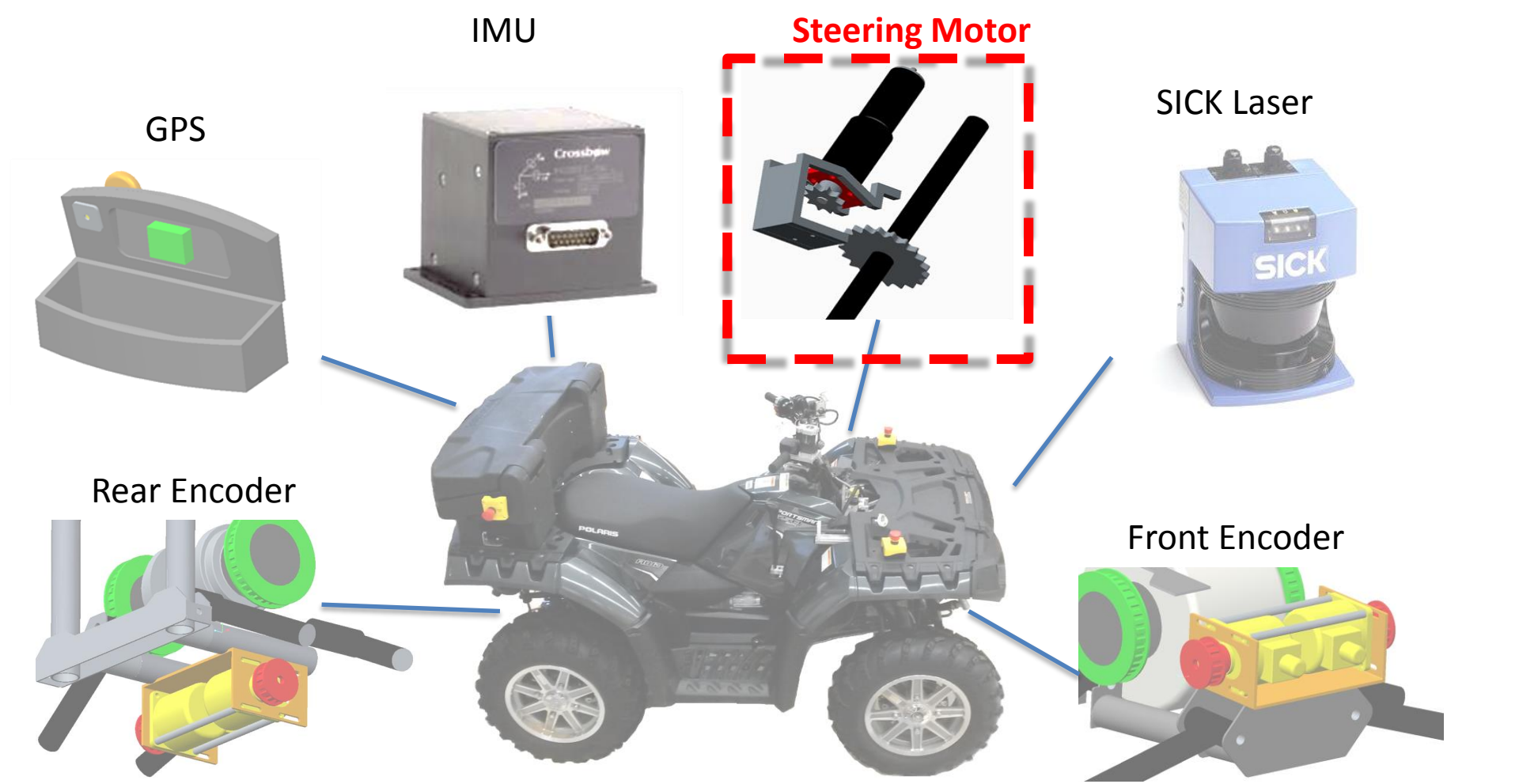
System Block Diagram



Computer/Router

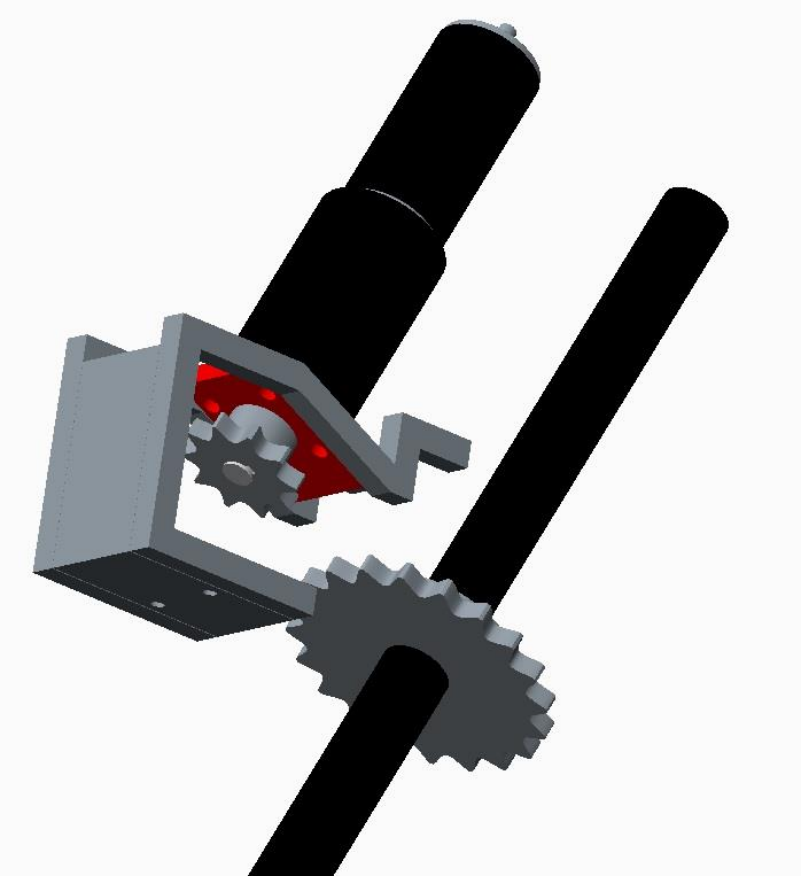
- ROS/Ubuntu Toughbook laptop
  - Lasers, IMU, GPS
- QNX Toughbook laptop
  - Encoders, actuators
- Chase Toughbook laptop
  - System monitoring
- Router TP- Link
  - 30 mile range

Steering Motor



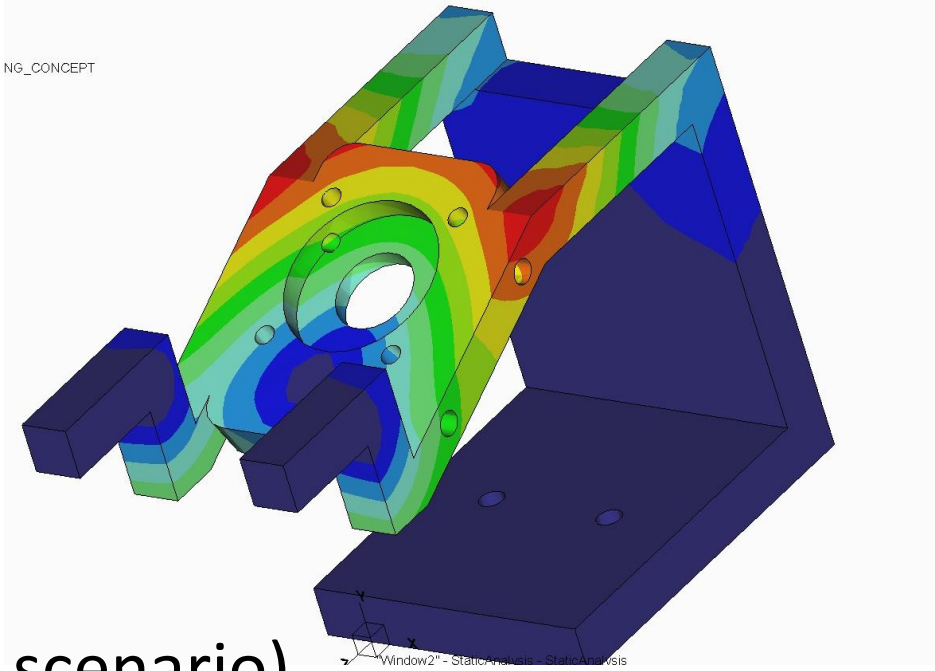
Steering Motor

- 24V DC brushed Maxon motor
- 8.92 Nm stall torque
- 100:1 Gearbox



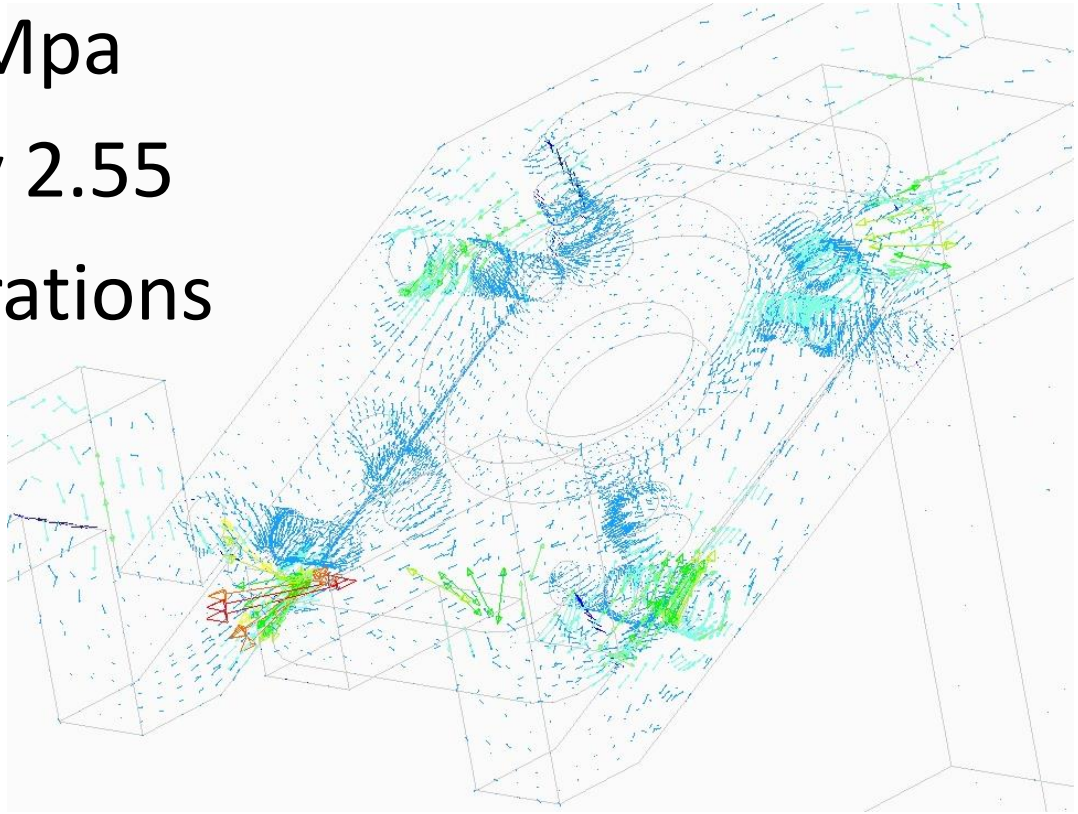
Steering Motor Mount

- No decision needed
- Modify existing mount
- 6061 Aluminum
  - Water Jet, CNC
- Finite Element Analysis
  - Stall torque (worst case scenario)
  - 892 Nm



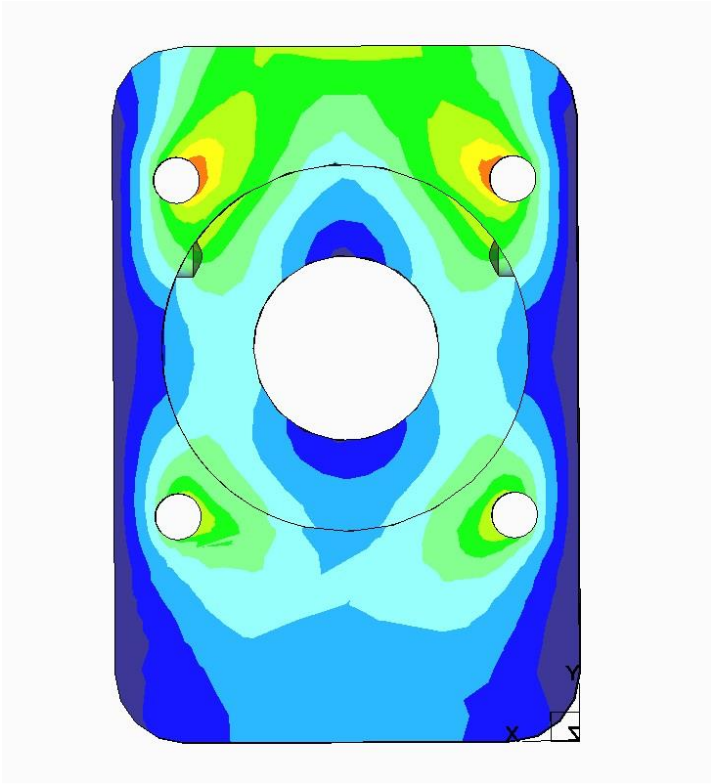
Steering Motor Mount

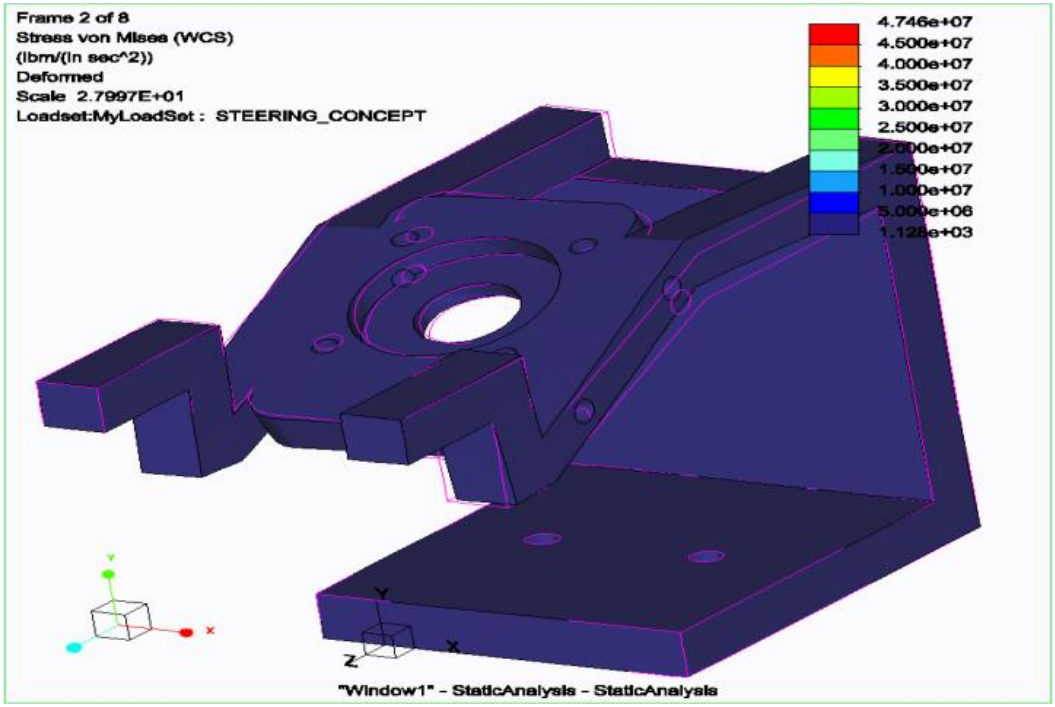
- 6061 AL yield strength 240 Mpa
- Max stress 95 Mpa
- Factor of safety 2.55
- Stress concentrations at bolt holes



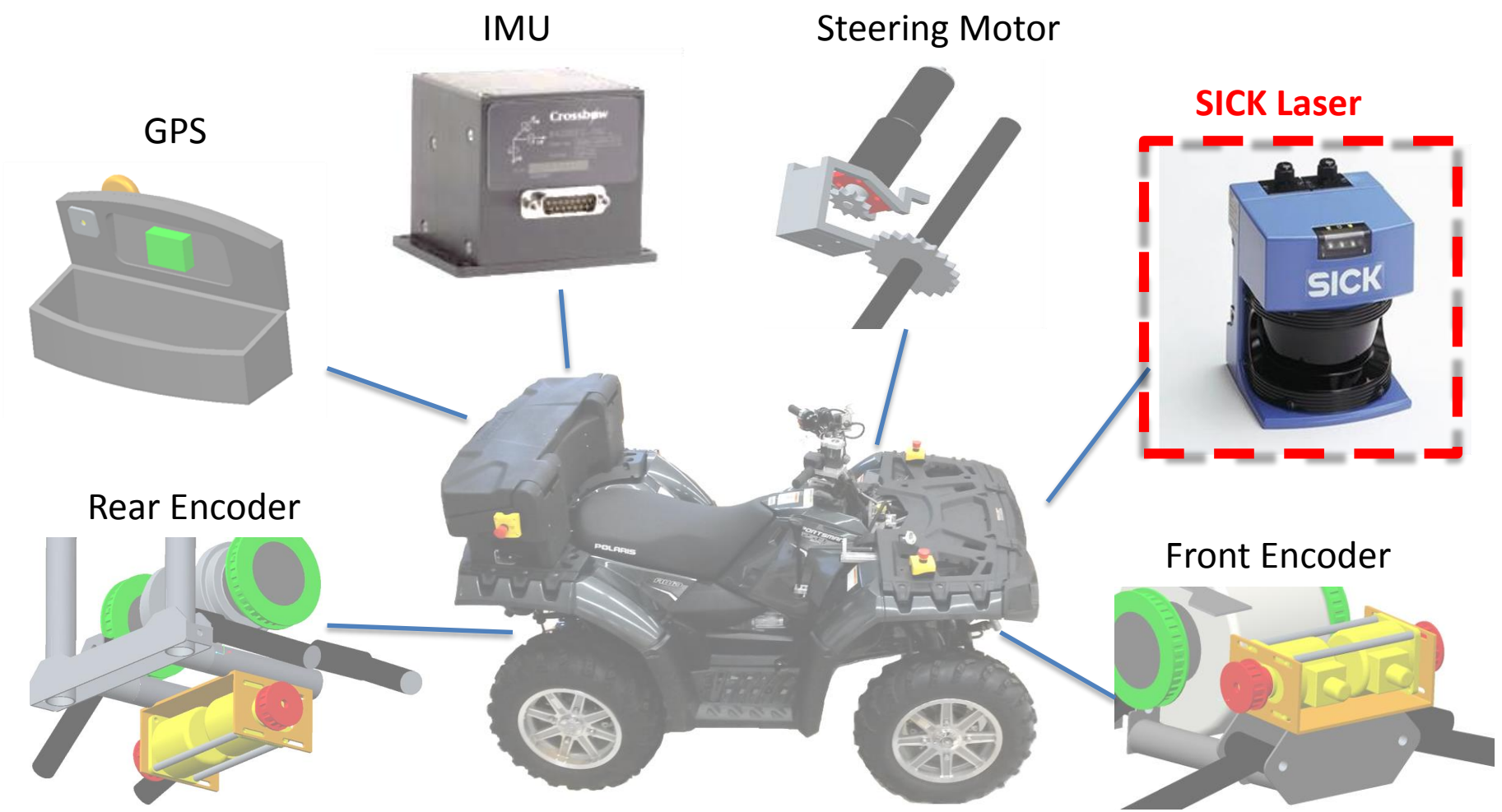
Steering Motor Mount

- Mount displacement



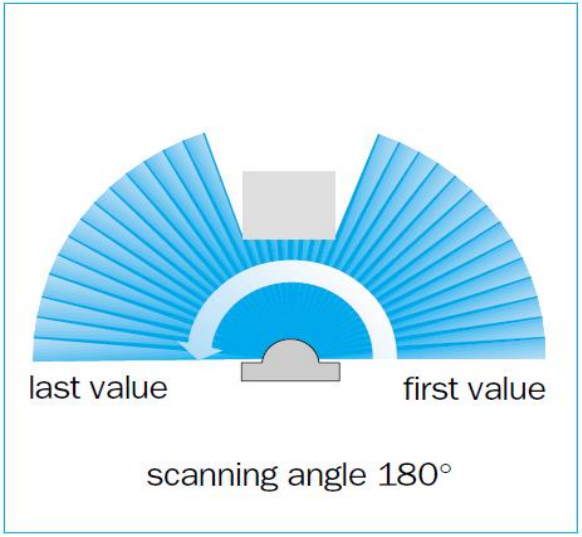


Laser


IMU
Steering Motor
GPS
SICK Laser
Rear Encoder
Front Encoder
Crossbow
SICK
POLARIS

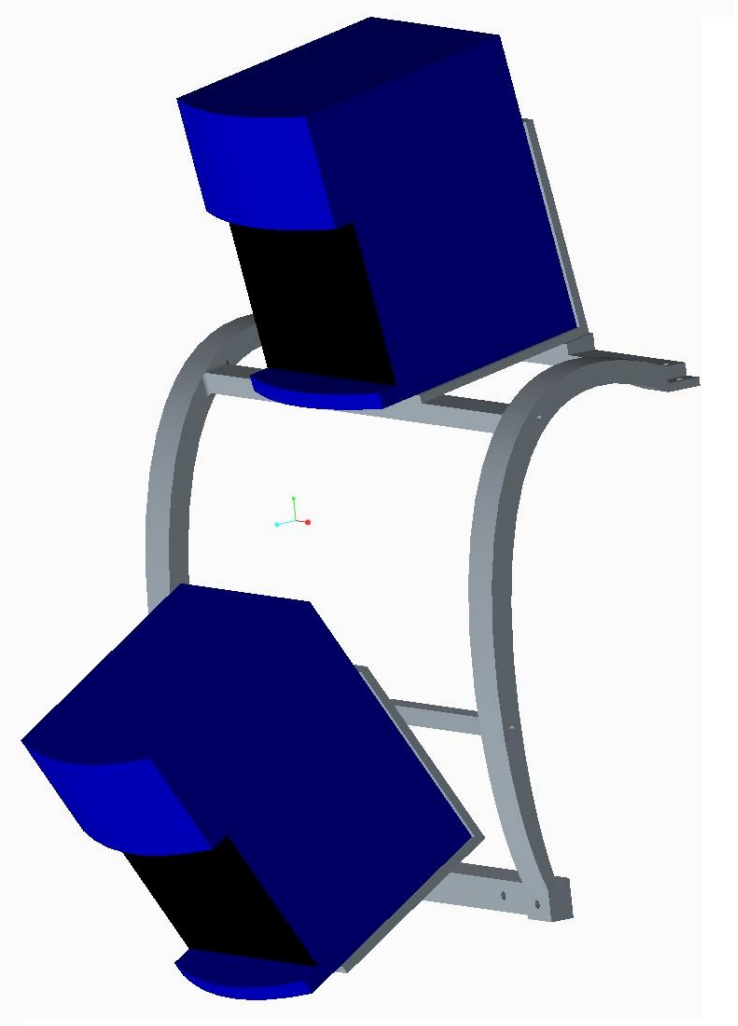
Laser

- SICK LMS-200 Laser Measurement System
- 180 degree scan profile
- Angular resolution
  = 0.25^{o}
- Two lasers
- 24V DC / 2.5A
- RS-232 to USB converter



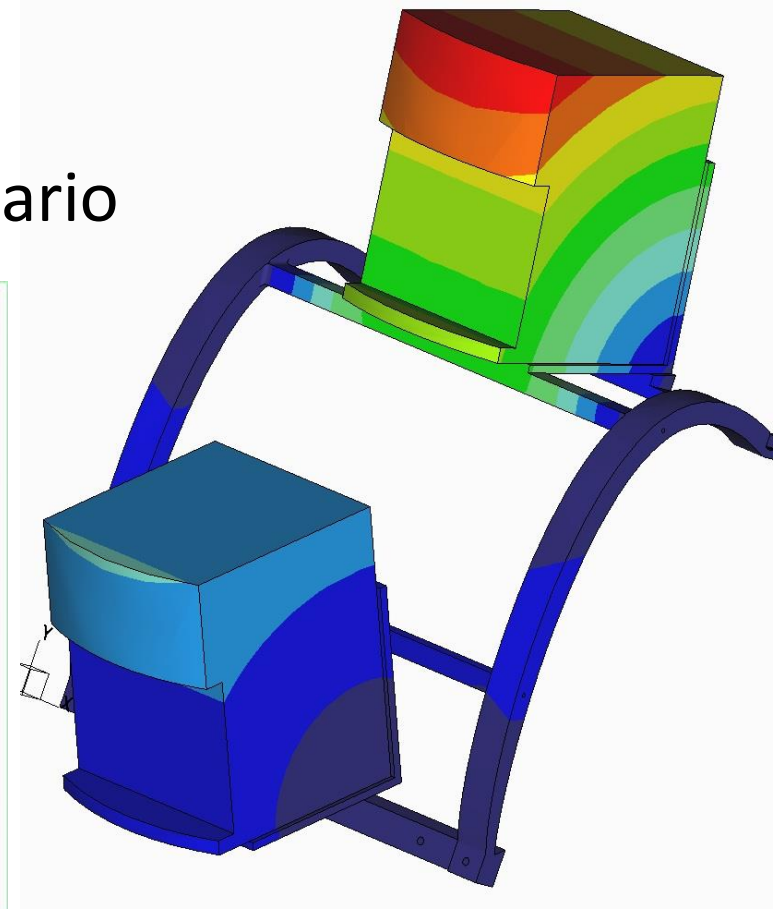
Laser Mount

- Stacked configuration
- Low interference
- Functionality
- Ease of calculation
- 6061 Aluminum
  - Water Jet, drill press



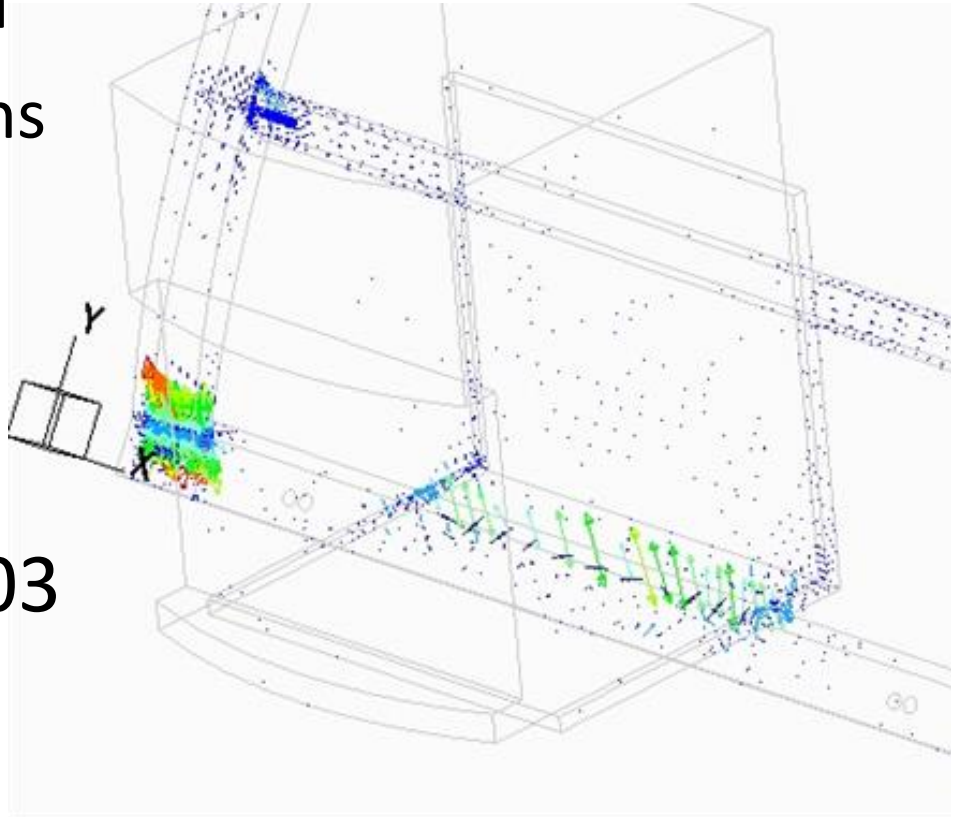
Laser Mount

- Simulate 20 mph collision
  - Assumed as worst case scenario



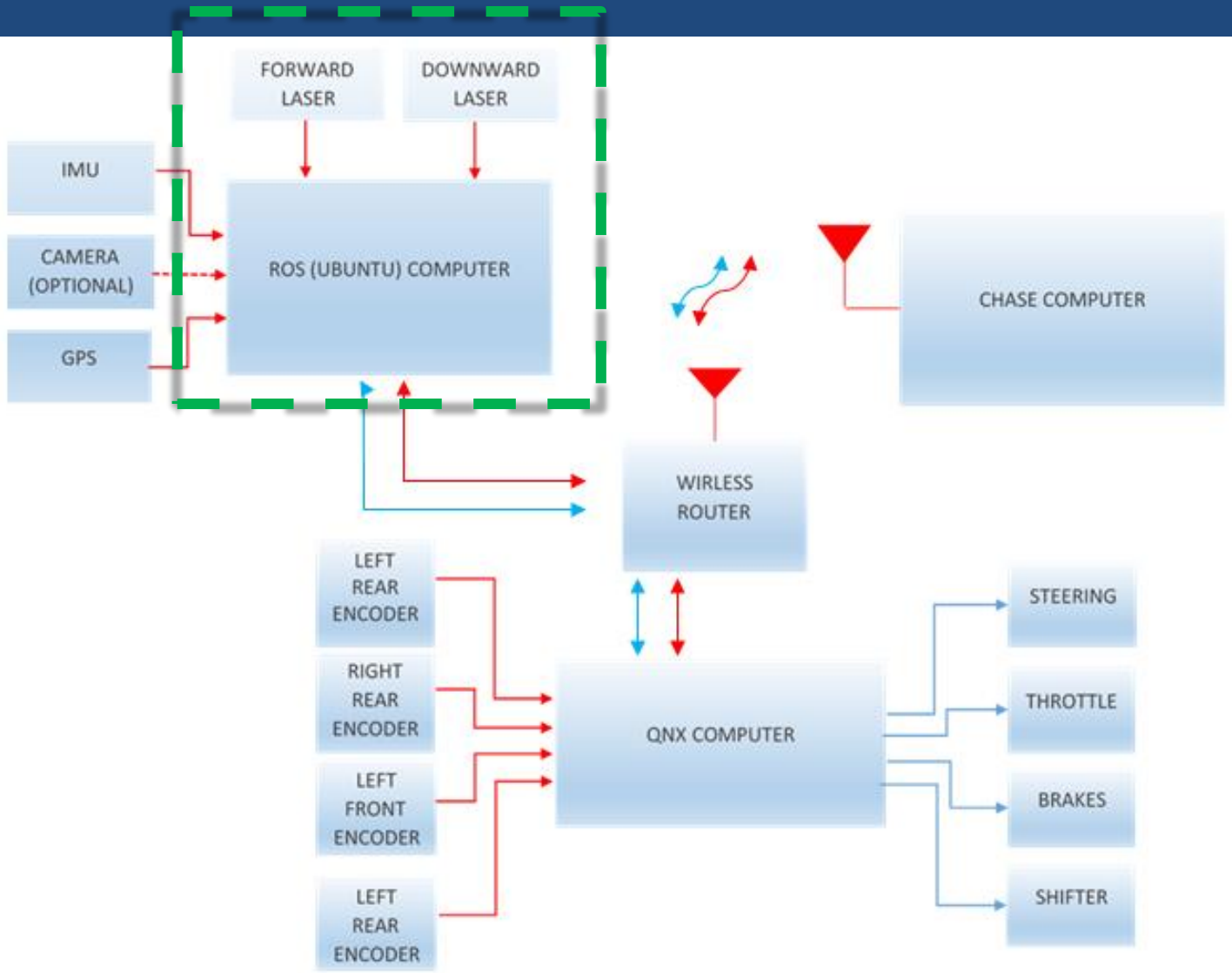
Laser Mount

- 6061 AL yield strength 240 Mpa
- Max stress 105 Mpa
  - Stress concentrations located at joints



- Factor of safety 2.303

Road Following



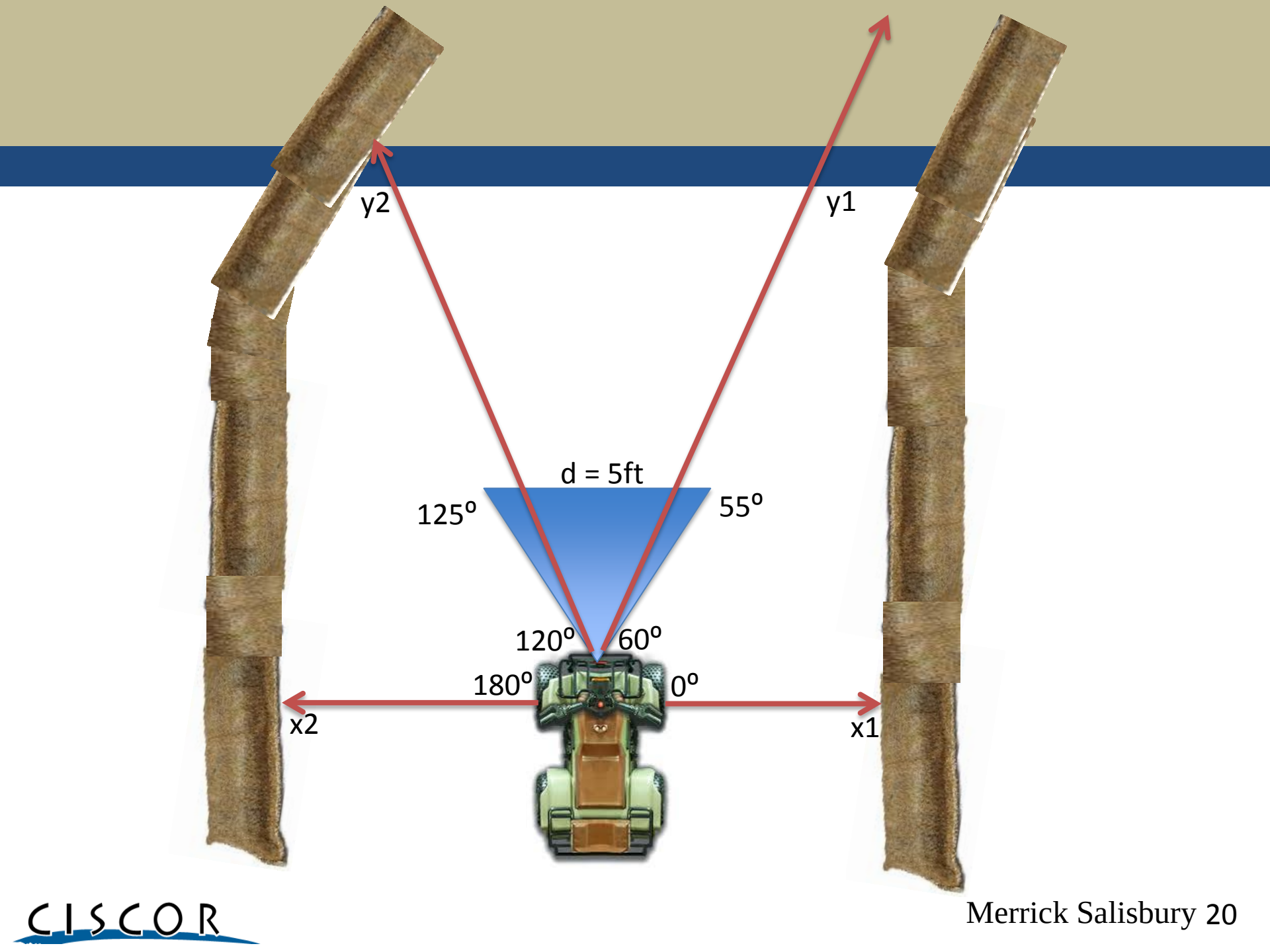
Road Following Pseudo Code

```
function firstsensor(s,d){
        int x1,x2,d,s,b
        IF (b<4.5feet) THEN
                Full brake to stop immediately
                        Spin
        ELSE
                Do nothing
        END IF
        IF (x1=x2) THEN
                IF (s>5) THEN
                        s = s
                ELSE
                        s = s + 1 //increment speed
                END IF
        ELSE IF (x1<x2) THEN
                d = -2      //turn left
        ELSE IF (x1>x2) THEN
                d = 2       //turn right
        ELSE IF (x1<<x2) THEN
                d = -4
                IF (s >1) THEN
                        s = s - 1
                ELSE
                        s=s
                END IF
        ELSE IF (x1>>x2) THEN
                d = 4
                IF (s >1) THEN
                        s = s - 1
                ELSE
                        s=s
                END IF
        ELSE
        END IF
}
```

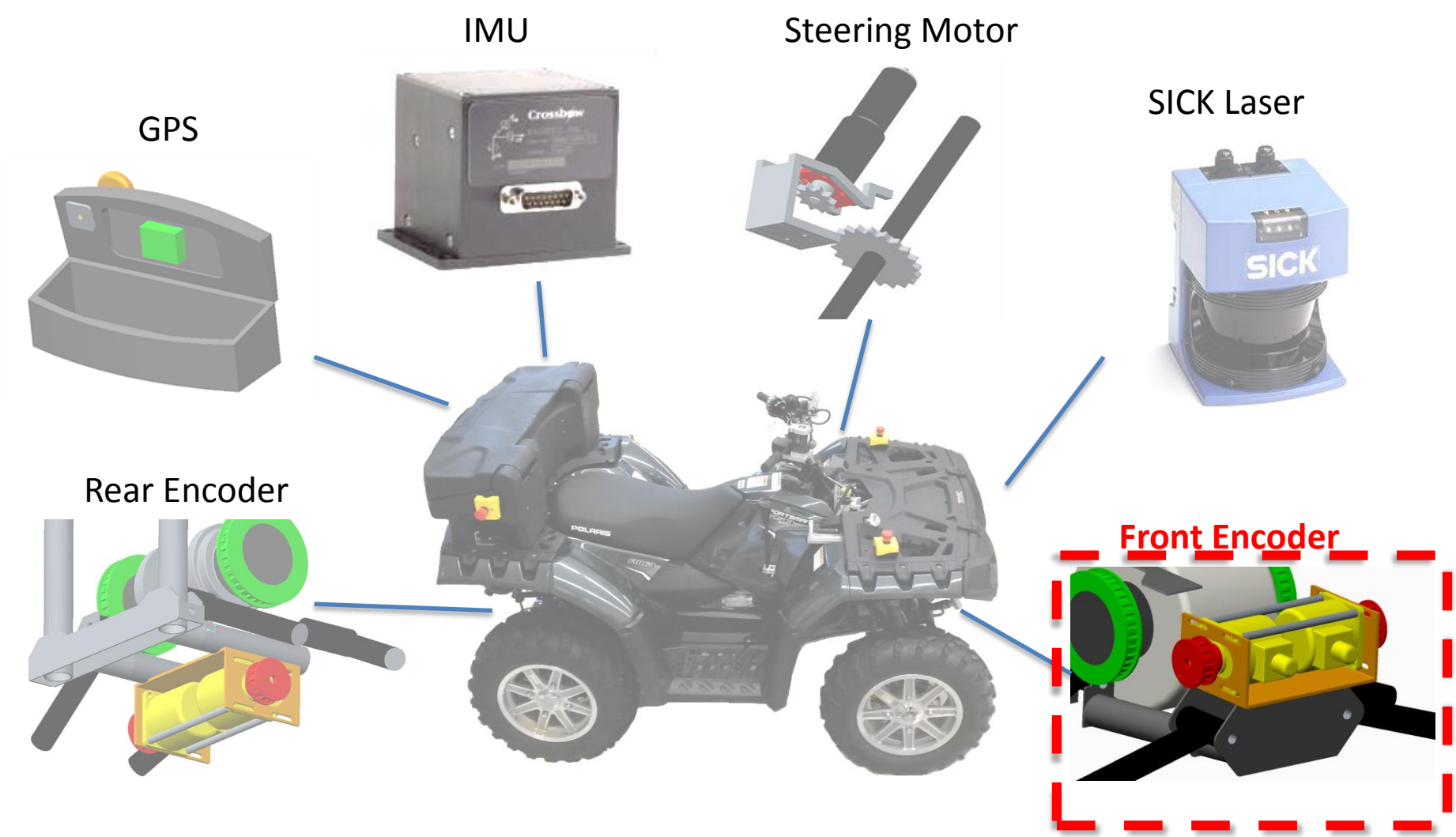
```
function secondsensor(s,d){
        int y1,y2
        IF (y1=y2) THEN
                s = s
        ELSE
                IF s < 3 THEN
                        s = s
                ELSE
                        s = s-1
                END IF
        END IF
}

main(){
        function firstsensor(s,d);
        function secondsensor(s,d);
}
```

```
Speed = s; Direction = d; Brake = stop flag; Shifter = forward;
//First sensors scans 3-5feet in front of the ATV
//Second sensors scans 15-20ft in front of the ATV
//x1 is the distance from road edge at 0 degrees(right side)
//x2 is the distance from road edge at 180 degrees (left side)
//d is the distance from an obstacle immediately in front of atv (ranged 55-125 degrees)
//y1 is the distance from the road at 60 degrees (right side)
//y2 is the distance from the road at 120 degrees (left side)
```

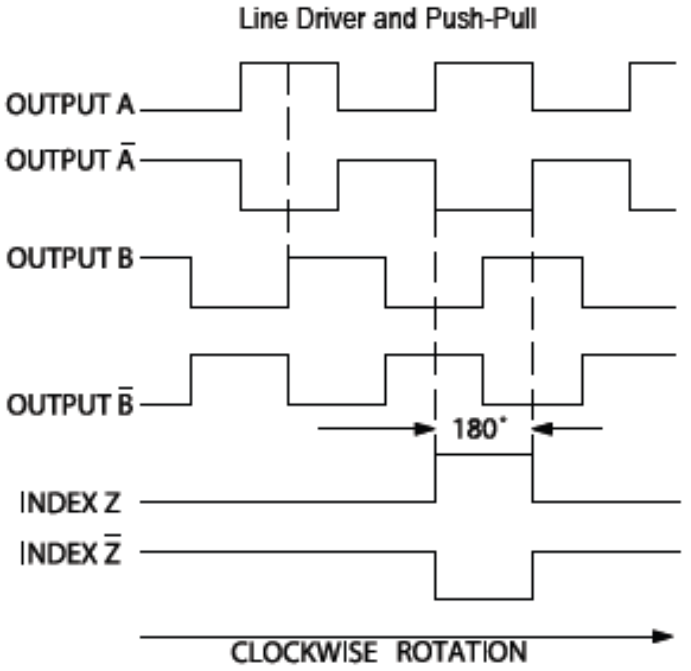

y2
y1
d = 5ft
125°
55°
120°
60°
180°
0°
x2
x1

Front Encoder Mount



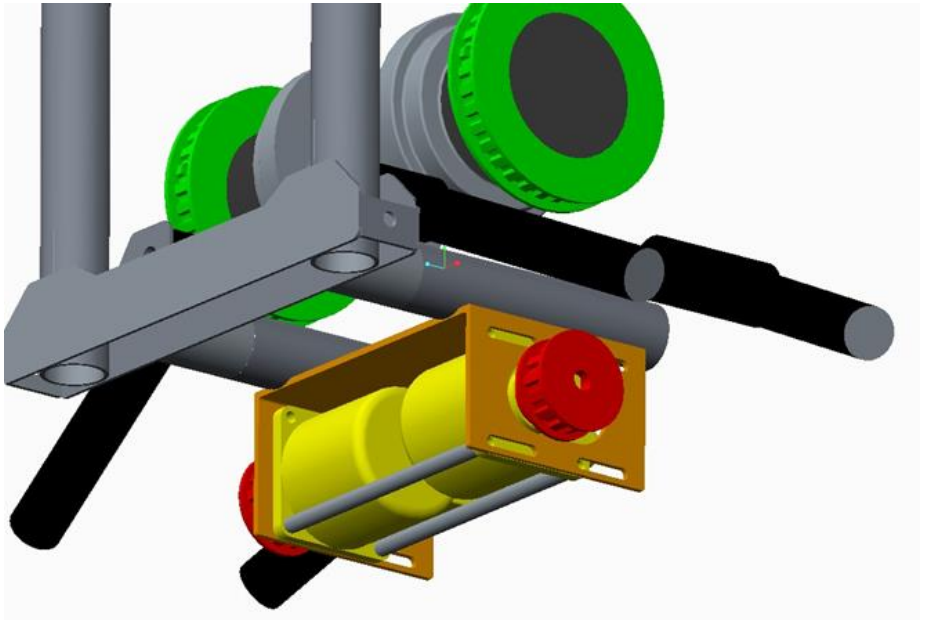
Encoder

- Accu-Coder 725 Encoder
- 30,000 counts per revolution
- Quadrature encoding
- 5-28 V DC



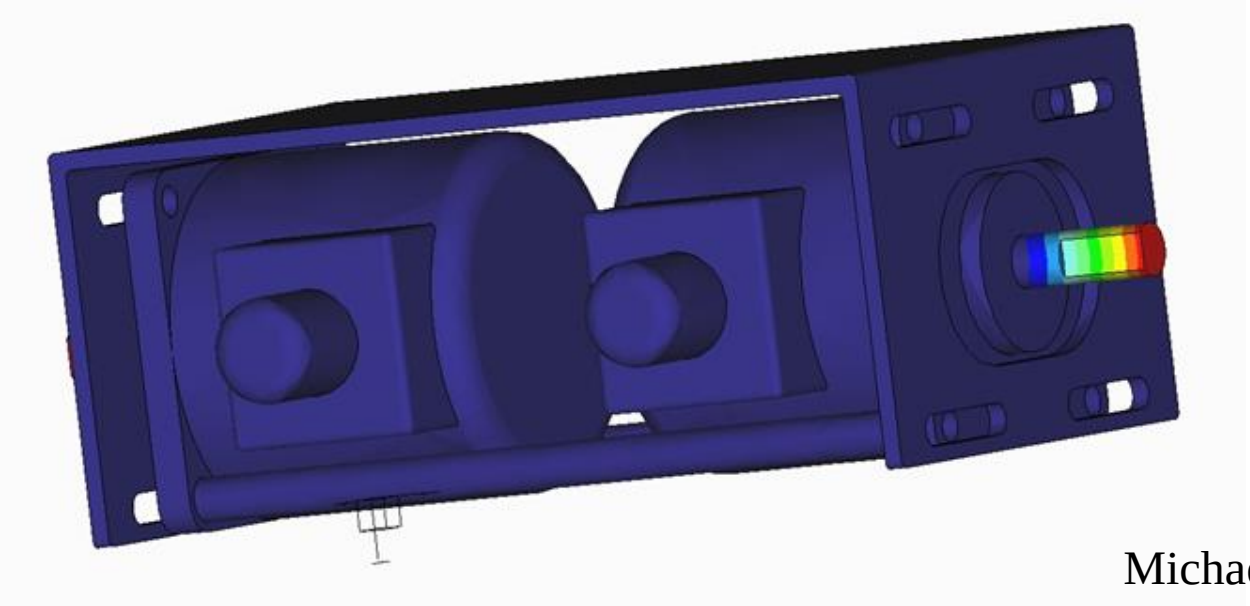
Front Encoder Mount

- Small interference
- Functionality
- Belt tensioner added
- 6061 Aluminum
  - Water Jet
- Possible impact from ground
  - Skid plate



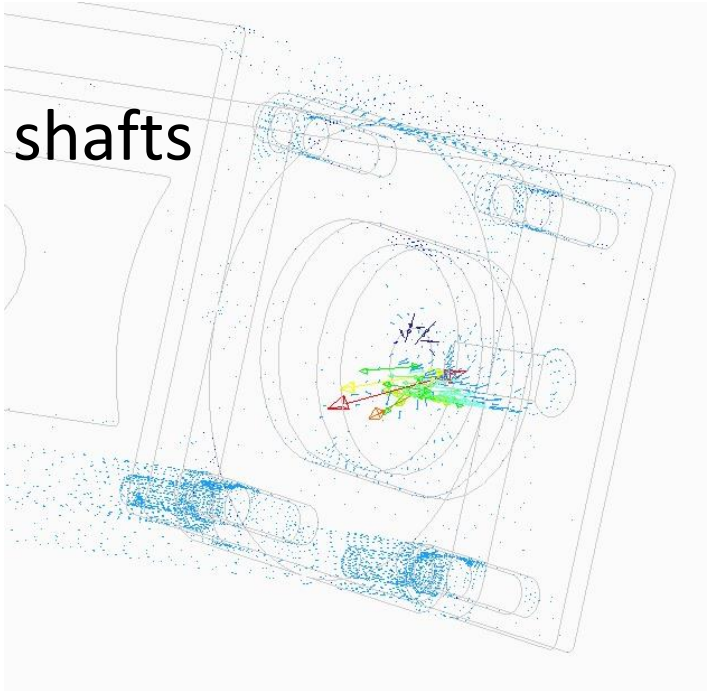
Front Encoder Mount

- Applied 80 lbf to encoder shafts
  - Maximum allowable load rating
  - Shafts made from 303 stainless steel
  - Support structure made from low carbon steel

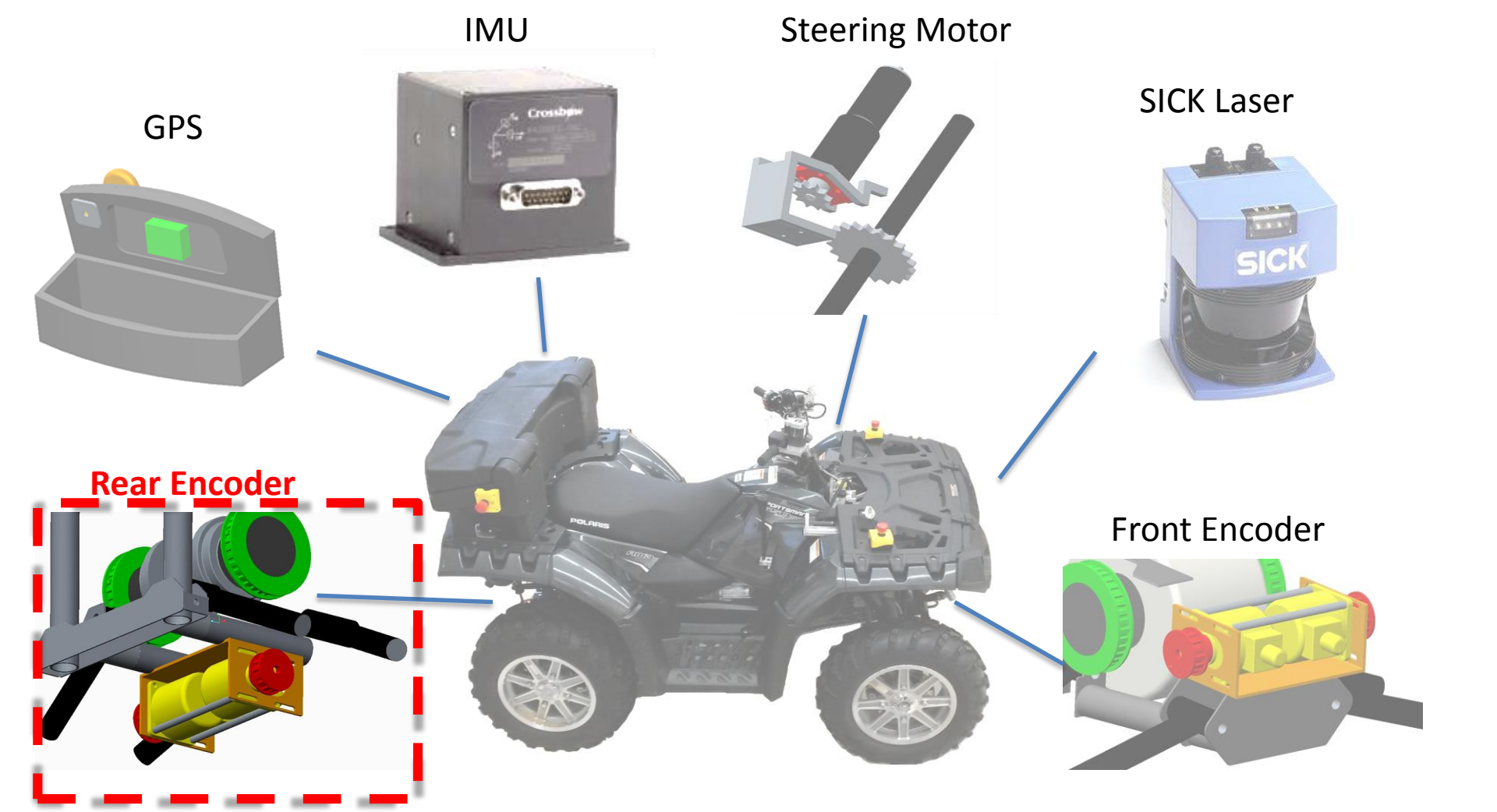


Front Encoder Mount

- Max radial load 80 lbf
- Stainless steel yield strength 200 Mpa
- Max stress 80 Mpa
  - Located at base of encoder shafts
- Factor of safety 2.49

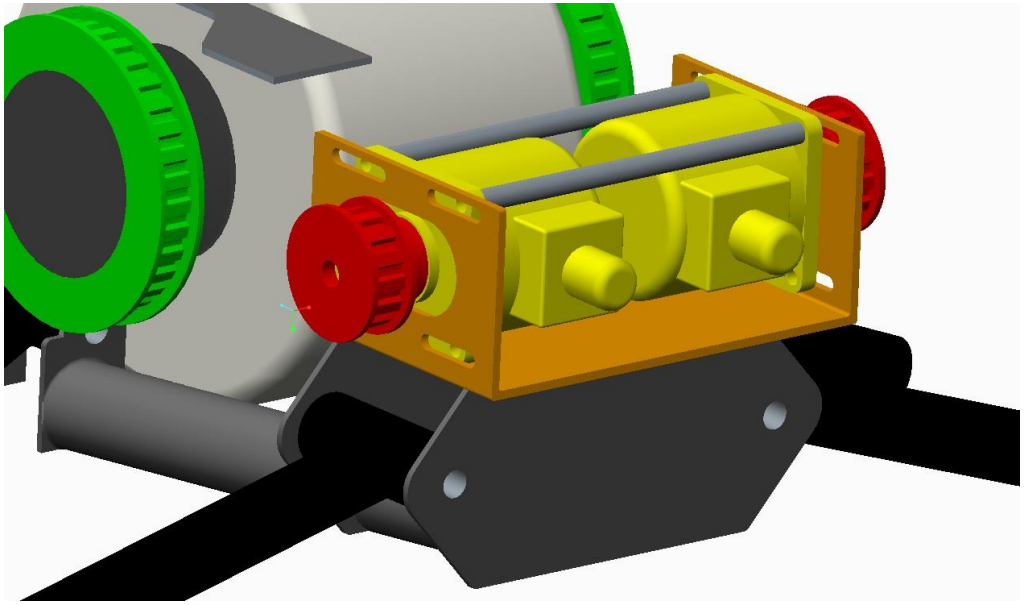


Rear Encoder

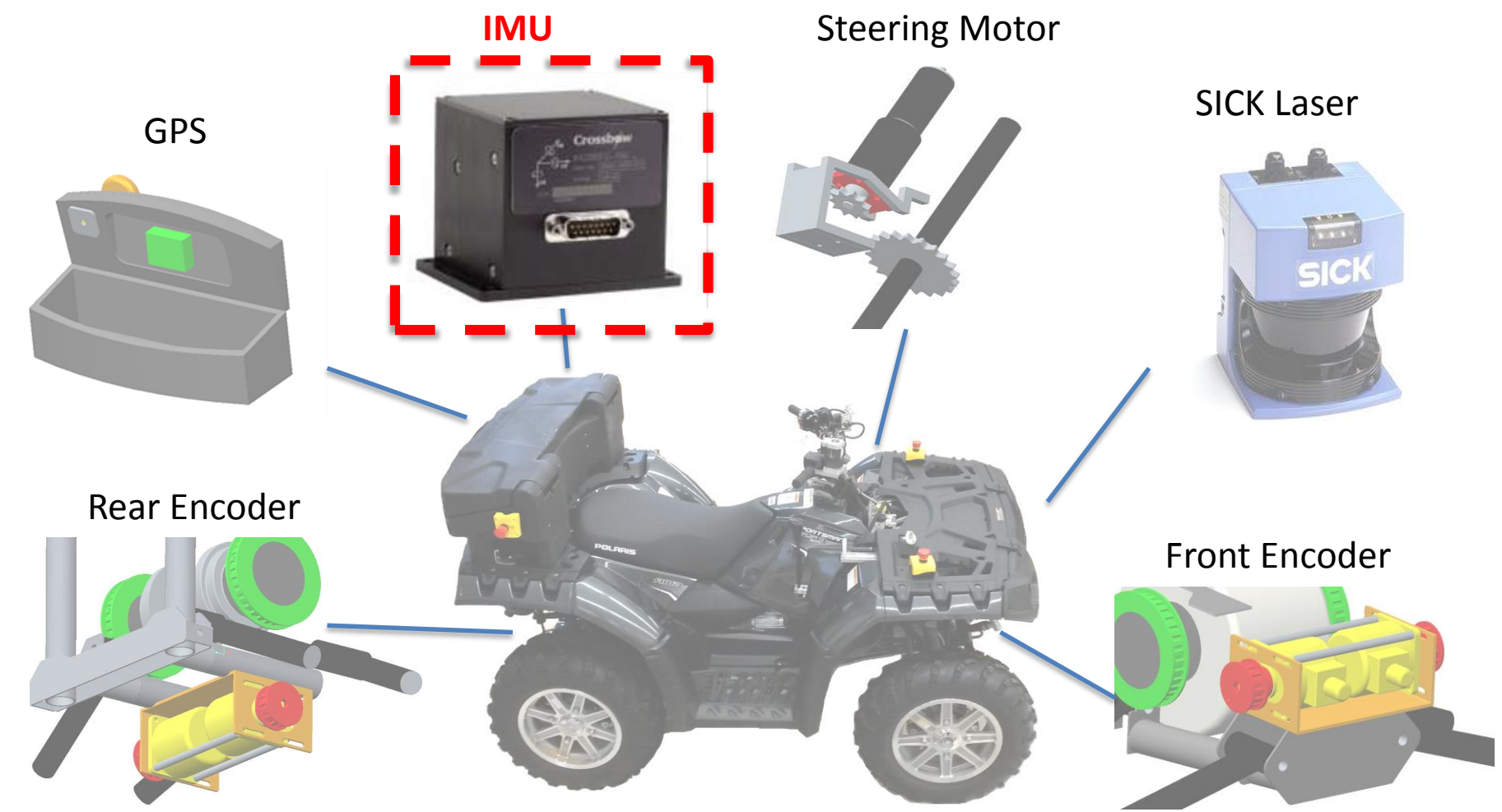


Rear Encoder Mount

- Same design as front encoder mount
  - Ease of manufacture
- Analysis already done



IMU


IMU
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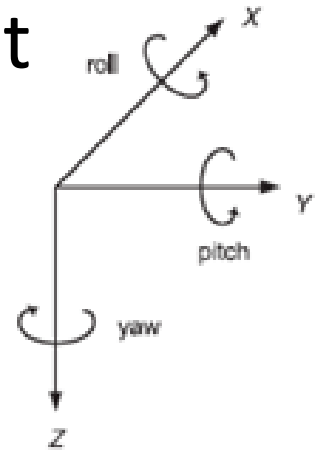
POLARIS

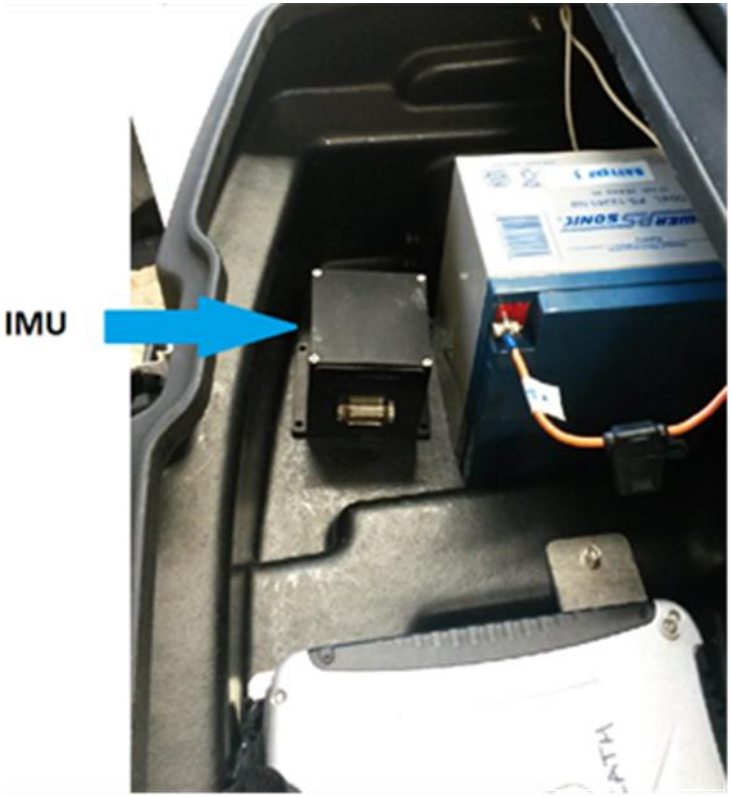
IMU

- Crossbow Inertial Measurement Unit
- Connections:
  - RS 232 (GPS)
- Power Requirements
  - +9V to +30V
    - < 250 mA (< 3W @ 12V)

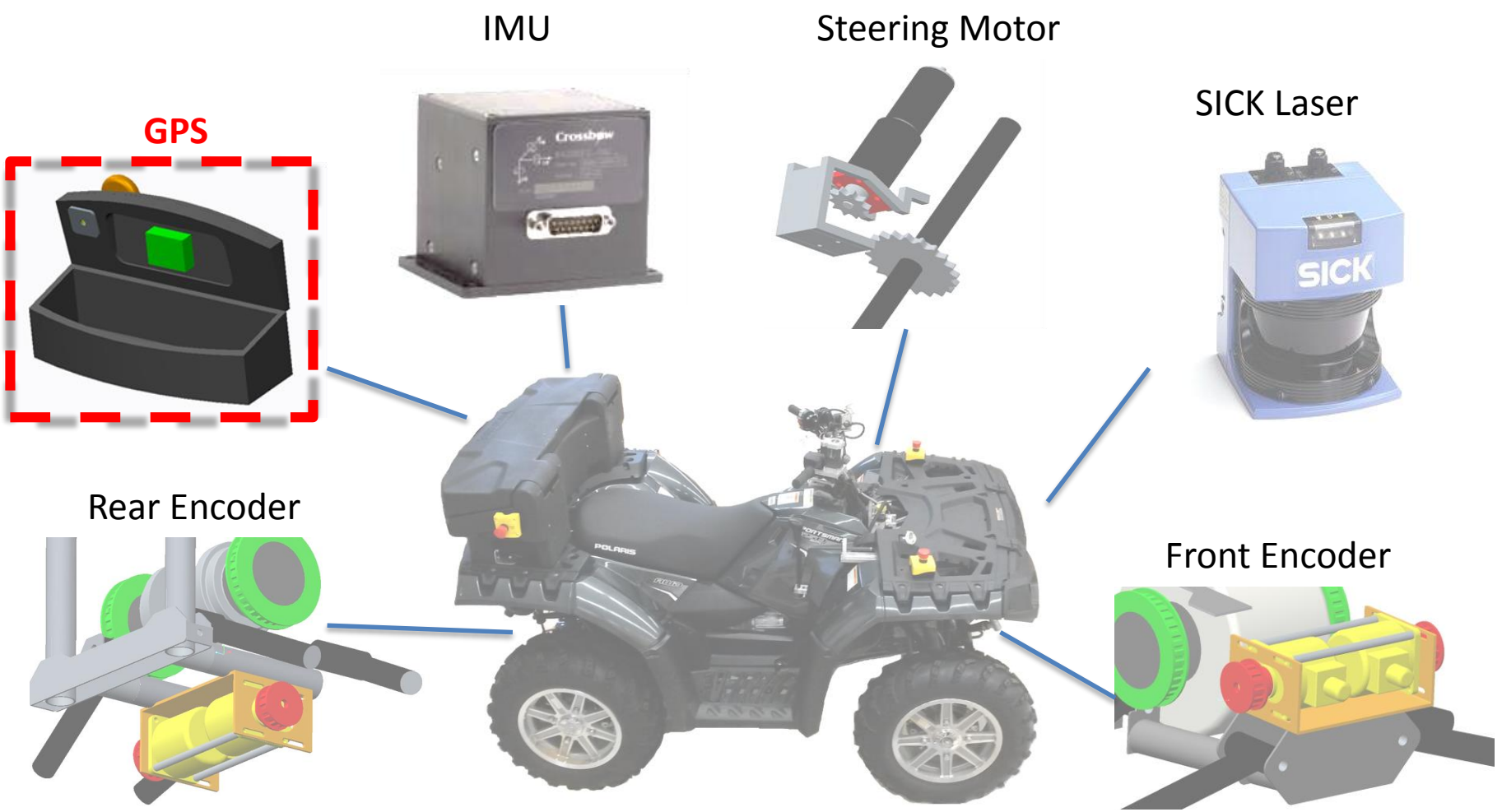


IMU Mounting

- Low susceptibility to damage
- No stress analysis
- Minimal manufacturing
  - Mounting holes



GPS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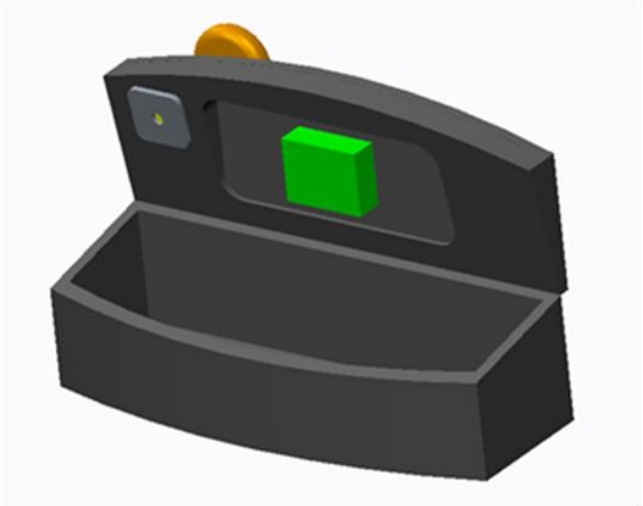
GPS

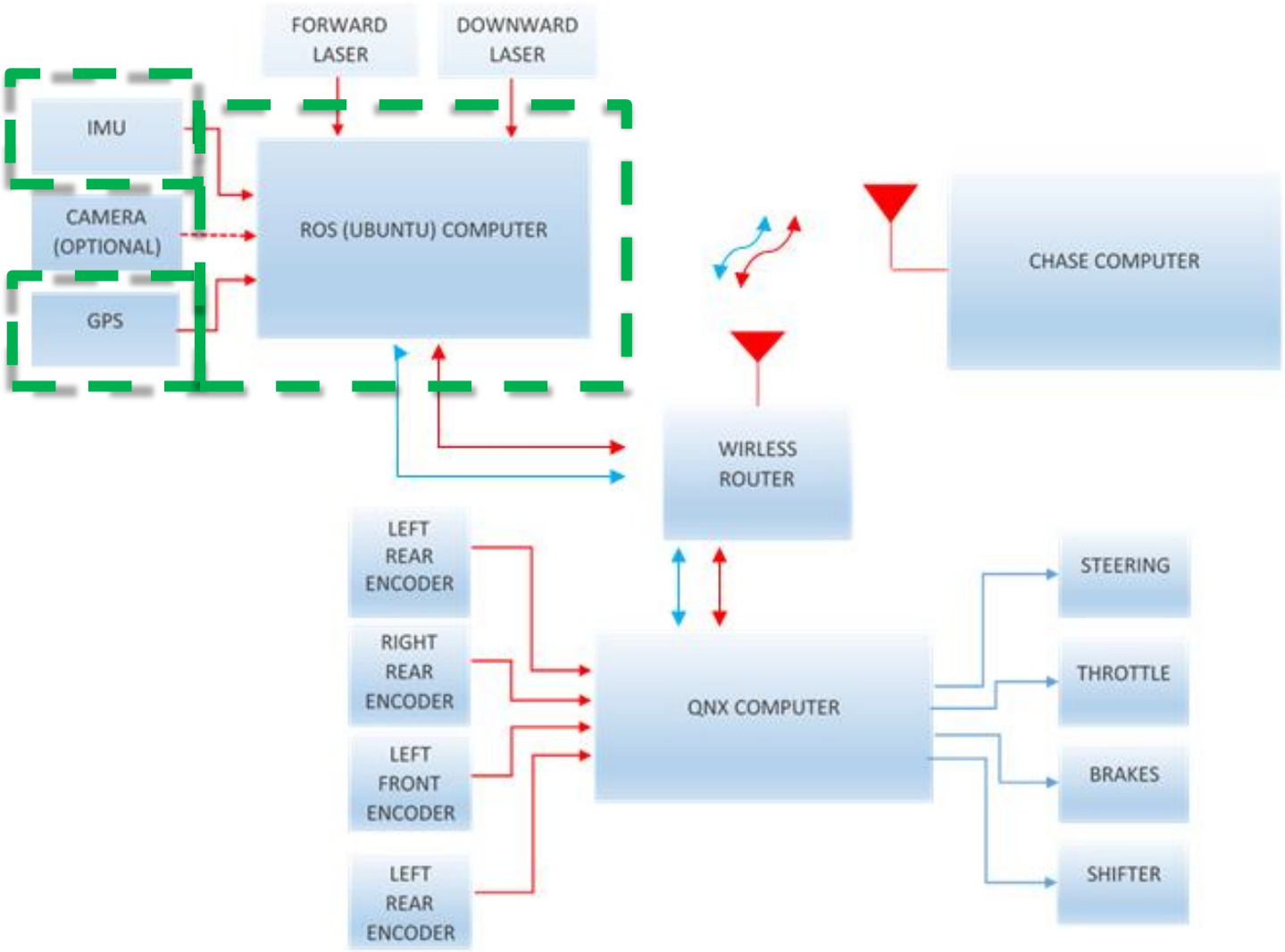
- Pro-Pack G2 plus GPS
- Connections:
  - RS 232 to USB Converter (CPU)
  - RS 232 (IMU)
  - Antenna Cable (GPS Antenna)
- Power Requirements:
  - +9V to +18V DC
    - 2.5W Power

GPS Mounting

- Small Interference with parts
- Low Susceptibility to Damage
- No stress analysis
- Antenna stabilizing plate
  - 6061 Aluminum
  - Water Jet



Waypoint Navigation

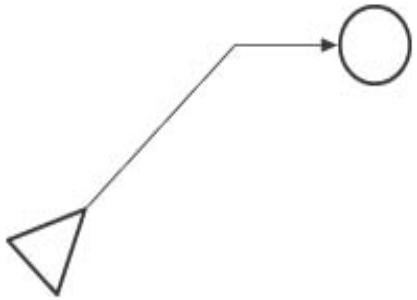


Waypoint Navigation

- Basic Path Finding Algorithm
  - Demonstration of system functionality

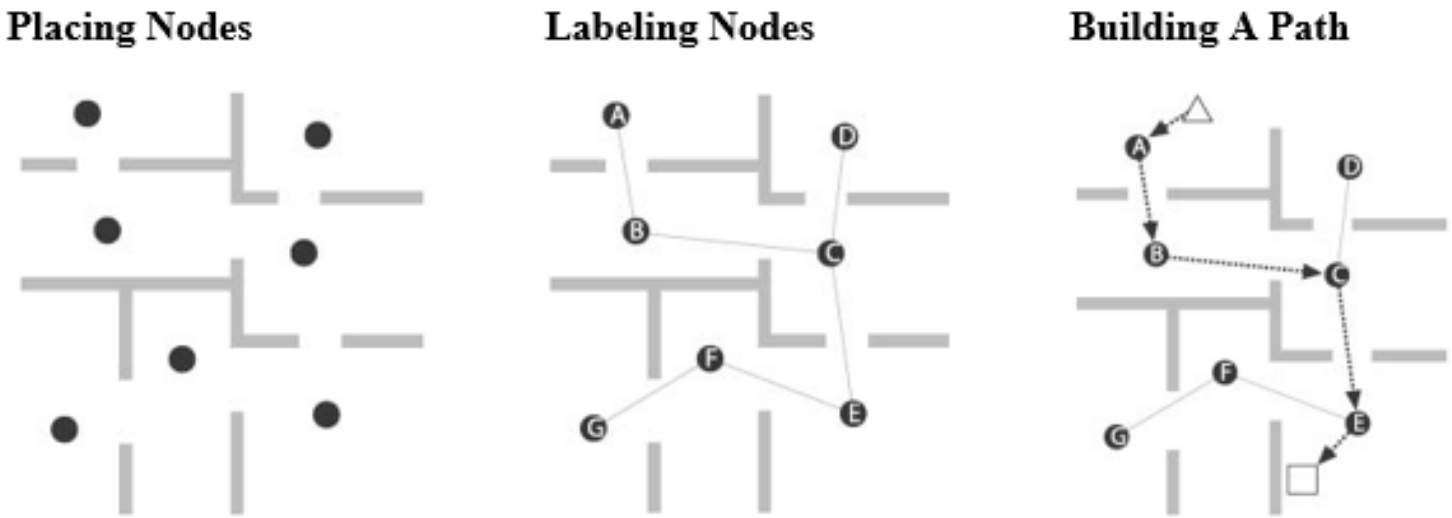
Basic Path Finding Algorithm:

```
Given a destination (x2,y2)
Record current position (x1,y1)
If x2 > x1
        Orient in Eastern direction
Else if x1>x2
        Orient in Western direction
While ( current position != destination)
        If x1 < x2
                x1← x1++    ; using the encoders to determine the necessary trajectory to
        else if  x1 > x2
                x1 ← x1 - -
        If y1 < y2
                y1← y1++
        else if  y1 > y2
                y1 ← y1 - -
```



Waypoint Navigation

- Navigation using multiple waypoints(or nodes)
  - Extension of Basic Path Finding Algorithm
  - Uses node table to determine best path of navigation



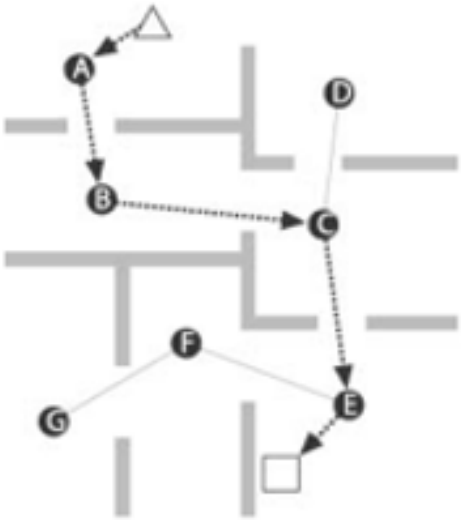
Waypoint Navigation

Functionality

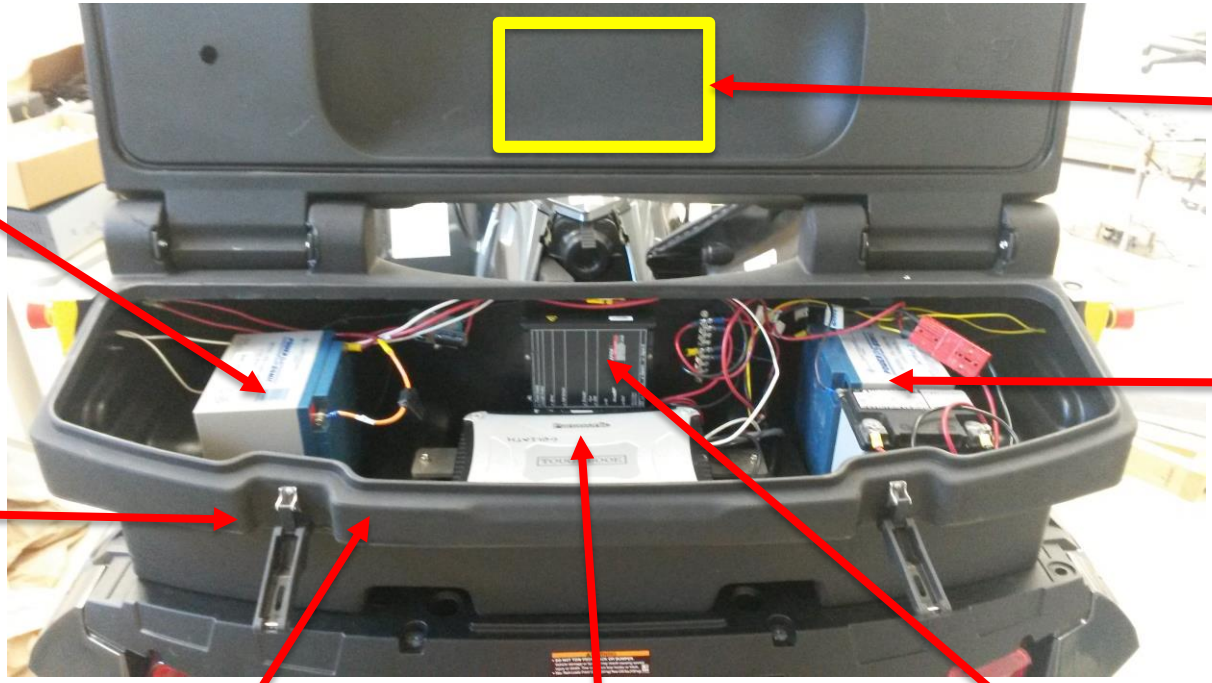
1. User places nodes on a map of the testing terrain
2. Nodes will be labeled in order of nodes that are most accessible
3. Node table is used to determine best path to destination

Node Table

Start \ End	A	B	C	D	E	F	G
A	—	B	B	B	B	B	B
B	A	—	C	C	C	C	C
C	B	B	—	D	E	E	E
D	C	C	C	—	C	C	C
E	C	C	C	C	—	F	F
F	E	E	E	E	E	—	G
G	F	F	F	F	F	F	—



Trunk Overview

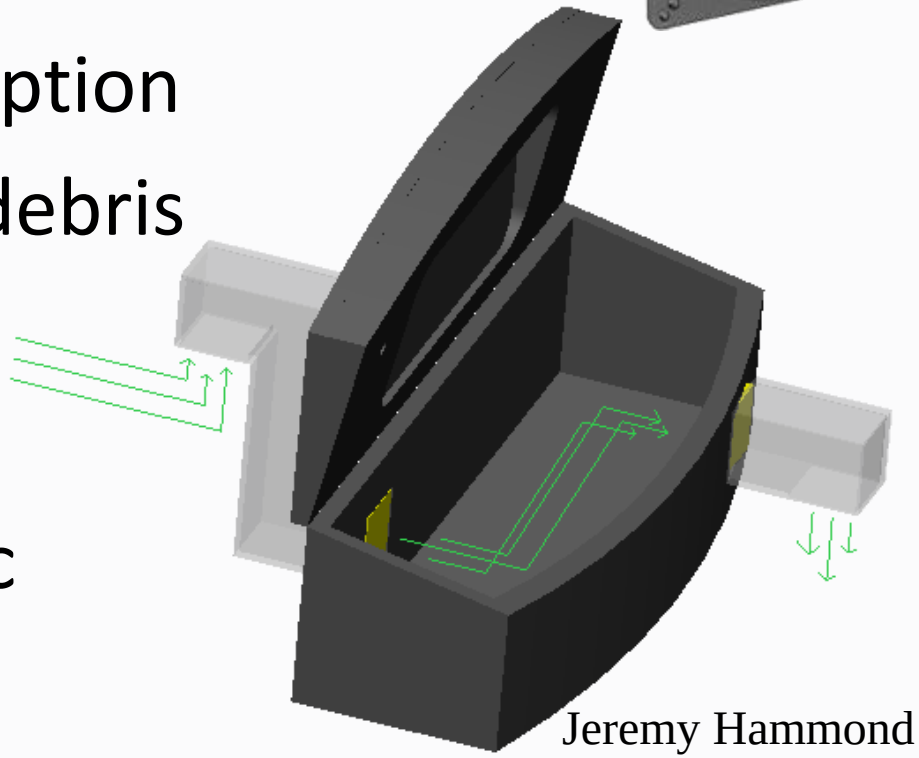


Heat Dissipation

- Refined power dissipation needs ~ 64.4W
- Analysis assumptions (worst case scenario)
  - Outside air temp 90 deg F
  - Isothermal internal surfaces 130 deg F max
  - Prandalt number [Pr], thermal conductivity [k], viscosity [u], density[p] of air taken at film temperature
  - Modeled as forced convection over flat plate

Heat Dissipation Solution

- 250 ft^3/min fan X2
  - 64.69 W theoretical heat dissipation
- Functionality
- Low energy consumption
- Snorkels for water/debris protection
  - Baffles
- Laser cut ABS plastic



Sensory Recap

- Road following
  - Lasers, IMU, encoders
- Waypoint navigation
  - Lasers, IMU, encoders, GPS
- Finalize sensor mount designs

Safety

- Autonomous control can yield unpredictable results
  - Errors in code
  - Wiring issues
  - Sensor malfunctions
- Software safety protocols
  - Release throttle, straighten steering, engage brakes
    - Obstacles
    - Loss of communication between computers or sensors
- Physical safety protocol
  - Spotter with remote power cutoff
    - Loss of communication with remote cutoff button

Parts/Resources

Website	Part	Number	Quantity	Price	Total Price
Mcmaster-Carr	205CFM fan	1939K96	2	73.42	146.84
Mcmaster-Carr	m5 0.8 20mm bolts for enc	91290A242	1	10.99	10.99
Mcmaster-Carr	0.5 in thick 18x18 in 6061 for laser	89155K29	1	152.43	152.43
Mcmaster-Carr	8mm Dia 6061 rod for enc	4634T14	1	4.68	4.68
Mcmaster-Carr	Marine Sealant	67015A51	1	21.55	21.55
Mcmaster-Carr	0.5 in thick 21 in long front belt	6484K147	3	10.33	30.99
Mcmaster-Carr	0.5 in thick 20.2 in long rear belt	1679K267	3	13.44	40.32
Mcmaster-Carr	nuts/ bolts/ fasteners		1	100	100
Amazon	RS232 to USB converter		4	14.95	59.8
				Total	567.6

- CISCOR workspace, machine shop, and tools
  - Laser cutter
- COE machine shop
  - Water Jet, CNC, end mill, lathe

Summary / Future Plans

- Mechanical designs have been finalized
- Structural and thermal analysis proves functionality of designs
- Remaining budget : 932.40 USD
- Communication with sensors still in progress
- Autonomous algorithms not fully developed
  - Pending collaboration with CISCOR researchers

Sources

http://sicktoolbox.sourceforge.net/docs/sick-lms-technical-description.pdf

http://www.novatel.com/assets/Documents/Papers/ProPakG2plus.pdf

http://saba.kntu.ac.ir/eecd/ecourses/instrumentation/projects/reports/Poly%20Gyroscope/Producers/Crossbow/IMU/6020-0019-01_B_IMU300CC.pdf

http://www.ctiautomation.net/PDF/Accu-Coder/Accu-Coder-725-Shaft-Encoders.pdf

http://www.maxonmotorusa.com/medias/sys_master/8807014760478/13_106_EN.pdf

Fin

Questions?

Comments?